Recycling Brines from Cucumber Processing

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ABSTRACT.

Spent curing brines from cucumber pickling present a disposal problem because of the large quantities of BOD and salt contained therein. A method was developed to recycle these brines. The method is simple and relatively inexpensive. It involves the use of sodium hydroxide (liquid) to adjust pH to 11, the addition of an anionic polyelectrolyte, a two hour settling period, decantation of clear brine, the adjustment of pH to 7 with acetic acid (vinegar) and application to a fresh lot of cucumbers. Cucumbers pickled using recycled brine are equivalent or better in quality to cucumbers treated in the normal manner with fresh brine.

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INTRODUCTION

The growing concern of mankind with environmental pollution problems has led to an increasing effort on the part of educational institutions, industry, governments, and society to find ways to reduce, arrest, and roll back the degradation of the environment. The general problem of industrial pollution abatement and that from food processing in particular is receiving the attention of a significant number of qualified scientists.

Sodium chloride (salt) is a significant contributor to the pollution of our environment. Although cucumber processing salt brines contribute a very small part to world's saline pollution, the problems they present are important to pickle processors and to communities in which they are located. A solution to the problems confronting pickle processors could be applied to the larger problems of industrial salt pollution.

The pickle industry is a growing business. In 1965, 6.8 million tons of cucumbers for pickling were produced. By 1974, this value increased by 1.5 million tons to 8.2 million tons. This represented a 45.2 million dollar increase in a nine year period or a 5.0 million dollar increase per year (1).

In 1954, the average individual consumed approximately 3.9 pounds of pickles per year. By 1973 the average individual was consuming 8.0 pounds of pickles per year, nearly twice the amount consumed in 1954 (1).

Cucumbers are processed as fresh pack, salt stock, or refrigerated dills. The fresh pack and refrigerated pickles do not create a major pollution problem but salt stock does.

Salt stock pickles are fermented in a brine containing from 7 to as high as 18% salt. This brine may contain 2000 ppm suspended solids and 12 to 16,000 ppm BOD. Approximately 30 million gallons of such brine is produced annually from the pickling process.

The United States produces more than 30 million tons of salt annually nearly all of it from practically pure solid deposits laid down millions of years ago by evaporation of ancient seas. The continued use of salt from such deposits can only increase the salt content of the earth's waters. This increase is first apparent in fresh or estuarine waters near the pollution source. It will eventually increase the salt content of the seas.

Regulations have been promulgated through the United States Environmental Protection Agency (USEPA) and other agencies which control the disposal of salt brines. These regulations emphasize the urgent need for a solution to this problem.

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This project was undertaken at the Department of Horticulture, The Ohio State University, and the Ohio Agricultural Research and Development Center to devise methods, equipment, and procedures which would provide a low cost, simple means for recycling "spent" cucumber pickle brines and thereby eliminate them as a source of saline pollution. Recycling of these brines was selected over other methods for preventing saline pollution because salt is not biodegradable and its removal from water requires a phase change.

The objectives of this work were to produce from spent brines:

1. A recyclable brine.
   a. A brine free of suspended solids.
   b. A brine without objectionable odor.
   c. A brine which does not contain softening enzymes.
2. A brine with an aesthetically pleasing appearance.

REVIEW OF LITERATURE

The literature specifically dealing with the reconditioning and recycling of food processing salt brines is limited (6,7,13,14,16).

Literature bearing upon the various aspects of the overall problem was reviewed. Only those references which have a direct application are cited under appropriate headings.

Water Treatment

The general problem includes in addition to the salt, soil carried in with the fruit, cucumber constituents leached from the fruit, and residues from the fermentation organisms present in the spent brine.

Behrman (3) reviewed the processes of water purification chemistry in lay terms and defined the methods as:

a. Plain sedimentation -- where particles are simply allowed to settle out.
b. Coagulation -- which is the process of collecting collodial particles into larger and heavier aggregates or clumps which will settle out.
c. Filtration -- where particles too large to pass through the filter pore space are removed.
d. Activated carbon filtration -- the removal of color and soluble organic materials.

Behrman (3) also described a "jar test" where different amounts of aluminum

sulfate and alkali were added to a measured amount of turbid water to determine what amounts and pH were best for a particular turbidity.

The U.S. Government (20,21,22) is the acknowledged world authority on the desalination of sea and brackish waters. The publications listed constitute a complete compendium of methods for the production of potable water and water for irrigation and industrial uses. These methods included: vertical tube evaporator distillation, multi-stage flash distillation, a combination of the two, vapor compression, solar evaporation, reverse osmosis, transport depletion, crystallization, and ion exchange. A review of this literature served to support the conclusion that recycling in the liquid state would be the most feasible solution for pickle processors.

Waste Treatment

The literature regarding food processing waste treatment deals predominantly with biological degradation of dissolved and suspended organic solids. The fact that salt is not biodegradable eliminated this method from consideration.

Early researchers in the field of saline waste disposal, Boruf (6) and Taylor (19) concluded that the only practical method for treating such wastes was dilution. Recently, Lowe and Durkee (13) demonstrated a submerged combustion unit coupled with an incinerator which ostensibly reduced organic waste to carbon which remained in the dry salt and gases which were driven off.

Cucumber Brining Practices

For a comprehensive treatment of cucumber brining practices, Etchells *et al*. (9) provided a compendium of almost thirty years of research. Jones, *et al*. (12) and Etchells and Jones (8) reported on chemical and bacteriological changes which occur in brine during cucumber salt brine fermentation. They pointed to the softening phenomenon which is of major concern in any attempt at reconditioning. These softening enzymes were introduced into the brine by microorganisms inhabiting the blossoms, ovaries and fruit of cucumbers (8,18). Enzymatic softening was not restricted to any geographic region (4) and increasing the salt concentration within the limits of bacterial fermentation did not inhibit enzymatic softening (5).

Reconditioning and Recycling of Food Processing Salt Brine

Popper *et al*. (16), Mercer, Maagdenberg, and Ralls (14), and Lowe and Durkee (13) working with olive brines either did not encounter an enzymatic softening problem or they did not consider it in their work. Cranfield (7) did not mention this potential problem in his work although he did state that

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the brine was heated to 96.7°C (206°F) as part of the process.

Mercer, Maagdenberg, and Ralls (14), Popper et al. (16), and Lowe and Durkee (13) demonstrated models to recondition and/or recycle spent food processing salt brines. The problem then becomes one of economics. Popper (17) demonstrated a very economical system. His concept combined a chemically produced precipitate with clarification and filtration. He described the physical system as a long narrow tank with porous walls, which operated at very low pressure to avoid the formation of a dense filter cake.

EXPERIMENTAL MATERIALS AND METHODS

There have been three phases of this work. One was conducted in the plant chemistry laboratory of the Department of Horticulture, Columbus, Ohio. The second phase was carried out at the H. W. Madison Company Division of the J. M. Smucker Company in Medina, Ohio. The third phase was a refinement of the technique developed in the first two phases and was evaluted both in the laboratory and at the commercial firm.

Laboratory Phase

Spent pickle brine was obtained from the commercial firm. Approximately 200 gallons of brine were used in this phase.

1. Raw Material Examination

The raw brines were examined to determine properties for comparison with the reconditioned brines in order to evaluate treatment effectiveness. The characteristics evaluated were as follows:

a. Visual Inspection
b. Salt Content
c. pH
d. Total Acidity
e. Suspended Solids
f. Total, Volatile and Non-volatile Solids
g. Mineral Content
h. Chemical Oxygen Demand (C.O.D.)
i. Dissolved Oxygen (D.O.)
j. Light Transmission
k. Spot Tests for Protein and Carbohydrate
l. Nitrogen

The foregoing evaluations were made according to standard methods (2,10,11,15).

2. Coagulant Screening Tests

Chemicals screened as coagulants included:

a. Sodium Carbonate (Na_2CO_3) - The "soda ash" used in many municipal water treatment systems.

b. Agricultural Lime ($CaCO_3$) - This material was given a very cursory examination because of its ready availability and very low cost.

c. Calcium Oxide (CaO) - In some parts of the United States calcium oxide is synonymous with lime.

d. Aluminum Sulfate ($Al_2(SO_4)_3$) - The common "filter alum" which is the chemical most widely used in water treatment for the removal of colloidal materials responsible for turbidity.

e. Sodium Hydroxide (NaOH) - Often called "caustic soda" is frequently used alone in water treatment. It is used extensively to maintain pH within ranges at which precipitation occurs. A concentrated liquid was used for ease in handling.

The reagents were rated as to the amount of coagulation obtained by adding varying quantities on the following scale: None = ---; Slight = +; Moderate = ++; and Maximal = +++.

3. Clarifier Filter

A clarifier filter as suggested by Popper (17) was designed and evaluated in both the laboratory and commercial phases.

4. Treated Brine Examinations

The treated brine was examined according to the same procedures as detailed under raw brine examination. Two analyses not performed on the treated brine were total acidity and suspended solids. Both of these characteristics were removed by the treatments.

5. Activated Carbon

The Calgon Corporation, Calgon Center, Pittsburg, Pennsylvania, furnished 120 pounds of their granular activated carbon "Filtrasorb 400". This carbon was carefully washed to remove fines and approximately ten pounds dry weight were filled into a polyethylene vessel 10 x 9 x 5.5 inches providing 495 cubic inches of carbon bed. No attempt was made to determine adsorption isotherms because these would vary widely even within a single tank yard and with the efficiency of the clarifier filter.

Commercial Phase

At the commercial pickling plant, treatments which produced the optimum results in the laboratory were evaluted. Treatments were carried out in 250

gallon lots in both wooden and polyethylene containers.

1. Raw Material Examination - The raw brines were visually inspected and assayed for pH and salt content as previously described. Settleable solids were determined with the aid of Imhoff cones and turbidity was measured with a Hach colorimeter.

2. Clarifier Filter - The clarifier filter as previously described was evaluated as well as an activated charcoal filter. These units were used as contiguous treatments.

3. Treated Brine Examination - The treated brine was examined in the same manner as the raw brine. A final treatment was also made to adjust the brine pH back to neutral with hydrochloric acid (HCl). Vinegar (acetic acid) was also used for this purpose. The neutralized brine was then used to cure cucumbers.

4. Evaluation of Pickle Quality - Cucumbers were cured following procedures in use by the commercial firm in both recycled brine and brine using new salt. Since the curing began in late September, the fermentation process proceeded slowly. Measurements were made of acidity, salt content and texture during the curing operation.

Refinement Phase

Since it was found that a 48 hour settling period was required to produce a clear brine, work was also undertaken to speed up this period to make it more commercially feasible. Two treatments were studied for this purpose. One was the construction and use of a rapid sand filter such as is used in treating water from swimming pools and the second was the addition of polyelectrolytes available from Calgon Corporation.

Sand Filtration

Construction of the Sand Filter - The sand filter was constructed of simple and easy to obtain materials. A 55 gallon barrel was utilized in the construction. A wooden flume was constructed in order to hold the 18 inch bed of filter sand. A false bottom was constructed in the 55 gallon barrel in order to support the flume and filter sand. The space between the false bottom and the actual bottom acted as a reservoir for the filtrate. A drain was connected to the bottom of the barrel so that the filtrate could be removed. A hole was cut on the side of the barrel just above the false bottom. This acted as a drain for the backwash material which collected between the barrel and the flume. Backwashing was accomplished by forcing water up through the filtrate drain, then through the reservoir and up through the filter sand.

Filtration Procedure - Three replications with duplicate samples for analysis were performed. Approximately 18 gallons of spent brine were used for each replicate. Before filtration, the barrel of spent brine was stirred. The filter was cleaned between replicates by backwashing with fresh water for 10 minutes.

Flow Chart -

55 Gallons of Spent Brine
↓
SBA ← 18 Gallons → Sand Filter

Sand Filter → Residue

Sand Filter → Filtrate → RBA

SBA - Spent Brine Analysis
RBA - Recycled Brine Analysis

Polyelectrolyte Addition With or Without pH Adjustment

Three different polyelectrolytes manufactured by Calgon Corporation were tested for their ability to produce a floc that would rapidly settle when added to spent brine. The treatments were replicated with duplicate samples removed for analysis. The polyelectrolytes are known by the following trade names:

Anionic Polyelectrolyte WT 2900

Cationic Polyelectrolyte WT 2870

Nonionic Polyelectrolyte WT 2690

Nonionic Polyelectrolyte WT 2690 - A stock solution of WT 2690 was prepared. A magnetic stirring bar and 500 ml of distilled water were added to a clean 600 ml beaker, which was placed on a magnetic stirrer. The magnetic stirrer was set at speed 4. Exactly 1.000 gm of WT 2690 was sprinkled into the agitated, distilled water and allowed to mix until completely dissolved. This solution was quantitatively transferred to a clean 1000 ml volumetric flask and diluted to the mark. One ml of this stock solution, when added to 1 liter of spent brine, is equivalent to 1 ppm. The stock solution was stable for two weeks.

Twelve 1 liter bottles with rubber stoppers were cleaned, and 1 liter of spent brine was added to each bottle. The following dilutions of stock solution were prepared and replicated:

0 ppm - Control
0.01 ppm - 1 ml to 100 ml H_2O, 1 ml/l
0.1 ppm - 10 ml to 100 ml H_2O, 1 ml/l
1 ppm - 1 ml/l
10 ppm - 10 ml/l
100 ppm - 100 ml/l

After the addition of the polyelectrolyte, the samples were mixed and then observed for the polyelectrolyte's ability to form a floc that would rapidly

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settle in comparison to the control.

Twelve more bottles with rubber stoppers were cleaned and to each, 1 liter of spent brine was added. Each 1 liter of spent brine was adjusted to pH 11, using 19 N sodium hydroxide and a Beckman Expandomatic SS - 2 pH meter. The same dilutions as above were prepared and replicated with polyelectrolyte additions after pH adjustment.

The samples were mixed and then observed as previously described.

Twelve more bottles were thoroughly cleaned, and to each, 1 liter of spent brine was added. The same dilutions were prepared and replicated. The polyelectrolyte was added and the samples were adjusted to pH 11 as previously described. Observations were made on the rate of floc formation.

Cationic Polyelectrolyte WT 2870 - A stock solution of WT 2870 was prepared in exactly the same manner as for the polyelectrolyte WT 2690. Dilutions of this stock were added to spent brine with and without pH adjustment as previously described. The rate and amount of floc formation were recorded.

Anionic Polyelectrolyte WT 2900 - A stock solution of WT 2900 was prepared. A magnetic stirring bar and 500 ml of distilled water were added to a clean 600 ml beaker, which was placed on a magnetic stirrer. Exactly 0.2000 gm of WT 2900 was sprinkled into the agitated water. After complete dissolution, the mixture was quantitatively transferred to a clean 1000 ml volumetric flask and then diluted to the mark with distilled water. One ml of the stock solution, when added to the 1000 ml of spent brine, equals 0.2 ppm.

Fourteen 1 liter bottles with rubber stoppers were thoroughly cleaned, and to each, 1 liter of spent pickle brine was added. Each dilution including the control (no polyelectrolyte) was replicated. The following series of dilutions of stock solutions were made:

0 ppm - Control
2 ppm - 10 ml/l
4 ppm - 20 ml/l
6 ppm - 30 ml/l
8 ppm - 40 ml/l
10 ppm - 50 ml/l
20 ppm - 100 ml/l
40 ppm - 200 ml/l

After each dilution was prepared, it was observed for the polyelectrolyte's ability to produce a floc that would rapidly settle in comparison to the control.

Fourteen more bottles were cleaned, and to each, 1 liter of spent pickle brine was added. Each 1 liter sample was adjusted to pH 11, using 19 N sodium hydroxide and a Beckman Expandomatic SS - 2 pH meter. The same dilutions as

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above were prepared and replicated with polyelectrolyte additions after pH adjustment. The samples were mixed and then observed as previously described.

The same dilutions as above were prepared and replicated. The polyelectrolyte was added and the samples were adjusted to pH 11. Observations were made on the rate of floc formations.

Analysis of Treated Brines - Only those polyelectrolyte solutions producing a floc that settled rapidly were evaluated for clarity, C.O.D., and photographed to give an indication of the effectiveness of the polyelectrolyte additions. Per cent salt, light transmittance, pH, total acidity, total solids, and ash were also determined on these brines.

RESULTS AND DISCUSSION

Since the research was conducted in phases, the results of these phases will be presented and discussed separately.

Laboratory Phase

Upon receipt of the raw brine, aliquots were taken and analysis were performed as previously mentioned. The results are given in Tables 1 and 2.

1. Raw Material Examination

Table 1. Average pH and Total Acidity with Visual Observations by Salt Content of Raw Spent Brine.

Salt Content	$\overline{X}$ pH	$\overline{X}$ Total Acid, as lactic	Visual Observations
°Salometer		%	
70	3.4	0.61	very turbid greenish color
50	3.8	0.68	turbid greenish yellow color

The 70° salometer brine was lower in pH and total acid (Table 1). The differences were expected since it has been the contention that higher salt concentration suppressed lactic acid fermentation organisms (21).

The 70° salometer brine had a slightly higher volatile solids content and a greater percentage of non-volatile and total solids (Table 2). The startling difference in the brines is in suspended solids. There are several explanations for this phenomena: (a) the 70° salometer brine had been holding cucumbers for about one year while the 50° salometer brine was only six months old, (b) the 70° salometer brine was received in steel drums lined with polyethylene and the

Table 2. Average Percent Suspended, Volatile, Non-Volatile and Total Solids by Salt Content of Raw Spent Brine.

Salt Content	Suspended Solids*	Volatile Solids*	Non-Volatile Solids*	Total Solids*
°Salometer	%	%	%	%
70	0.71	1.10	22.51	23.67
50	0.19	1.20	14.82	15.75

*Average of 8 replicates

linings ruptured, (c) no complete analysis of spent cucumber brines was available, therefore; quantities of cucumber constituents extracted by various brine strengths is unknown. It seems reasonable that more concentrated brines would extract greater quantities of constituents because of increased osmotic pressure, (d) mechanical damage to the pickles as they were removed from the tank could add substantial quantities of solids to the brine.

Results of the mineral analysis will be presented with that for the treated brines. The raw spent brine contained an average of 7,000 ppm C.O.D. and 0 ppm D.O., as would be expected. Protein and carbohydrate spot tests were both positive. Light transmission data will be discussed separately.

2. Coagulant Screening Tests

A series of screening tests were performed for each of four reagents commonly used in water purification. In addition, combinations of agricultural lime and sodium carbonate were evaluted. The results (Table 3) can be summarized as follows:

1. Agricultural lime at concentrations between 2,500 and 16,250 ppm and aluminum sulfate at 100 to 4,000 ppm were not effective coagulants.
2. Sodium carbonate was effective in the 4,300 to 4,600 ppm range.
3. Calcium oxide was effective in the 1,000 to 2,000 ppm range but was expensive.
4. Sodium hydroxide was effective on both 50° and 70° salometer brines and was inexpensive.
5. The combination of agricultural lime and sodium carbonate produced coagulation only at the highest concentration.
6. There was no coagulation with any reagent until a pH of 6.8 was reached with maximum coagulation occurring at pH 11.0.

These results were used as a basis for enlarged tests for treatment of brine.

Table 3. Evaluation Screening of Standard Water-Treatment Reagents for Coagulation of Suspended Solids in 70° Salometer Brine.

Calcium Oxide		Sodium Hydroxide		Sodium Carbonate	
conc. ppm	result[a]	conc. ppm	result[a]	conc. ppm	result[a]
100	---	1000	---	3120	---
200	---	1200	---	3328	---
300	---	1400	---	3536	---
400	---	1600	---	3744	+
500	---	1800	+	3952	+
600	---	2000	+++	4160	++
700	+	1500[b]	---	4368	+++
900	+	1900[b]	---	4570	+++
1000	++	2100[b]	+	4784	++
1100	+++	2300[b]	++	5200	+
1200	+++	2500[b]	+++	5408	---

[a]Coagulation: None = ---; Slight = +; Moderate = ++; Maximal = +++.
[b]Salometer brine.

3. Clarifier Filter

A clarifier filter was utilized with larger quantities of spent brine. Several filter materials were evaluated including: monofilament polypropylene, multifilament polypropylene, cotton and cotton precoated with a filter aid. Of these materials, the precoated cotton hose performed best under laboratory conditions.

When the brine was adjusted to pH 11.0 with sodium hydroxide, the precoated cotton hose aided in removing the coagulated residue completely. This treated brine was then passed through a filter bed of activated charcoal. The resultant brine was crystal clear and colorless. A final treatment with HCl was given to adjust the pH to neutral. This adjustment chemically produced additional salt as: $HCl + NaOH \longrightarrow NaCl + H_2O$

4. Treated Brine Examination

Since all treatments involved pH adjustments the treated brine pH will not be given in tabular form. The color of the treated brine was bright yellow to clear. Salt concentration was essentially the same as the original brine.

The total solids were reduced slightly, about 1%, with the majority of total solids being non-volatile. Precipitation evidently removed some volatile solids as well as suspended solids.

The removed suspended solids were analyzed for plant nutrient content; i.e., minerals (Table 4).

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There are several items worth mentioning from the data in Table 4. Note the iron content of the 70° salometer raw brine. As was previously mentioned, this brine was obtained in steel drums and the polyethylene liner burst. Iron corrosion is readily indicated.

Nitrogen content was reduced by all treatments. This related to the partial or complete reduction of protein content in the brines.

The most interesting aspect is the consistency of the sodium data indicating essentially no removal of sodium. This is in agreement with the salt concentration data.

The C.O.D. of the treated brines was reduced by 50% by the poorest treatment. The treatment which was best reduced C.O.D. to an average of 200 ppm or by more than 97%.

As reported for raw brine, the D.O. of treated brines was 0.

The light transmittance data gave an indication of turbidity as well as efficiency of suspended solids removal. This test is rather simple and could be used "in-plant" as an evaluation or control technique.

The spot tests also were useful in determining efficiency of removal of carbohydrate and protein. It should be noted that the ideal treated brine would be negative for both tests. These tests would also be useful "in-plant" tools.

The micro-Kjeldahl tests confirmed the results of the spot tests (Biuret). With these results, the commercial scale tests were then conducted.

Commercial Phase

At the commercial plant aliquots of spent brine were titrated with NaOH. By ratio, calculations were made as to the amount of NaOH to add to the tanks for precipitation at pH 11.0. The raw brine was also examined for turbidity and settleable solids.

The treated brines were pumped through the clarifier filter and activated charcoal filter. Needless to say, there were some mechanical difficulties but these were overcome rapidly and a workable system resulted. However, after assaying cost of pumping, filtering and activated coal it was decided that these steps could be eliminated by allowing the precipitate to settle and then decanting the liquid brine. Settling periods of 24 and 48 hours were utilized. In addition, duplicate treatments with and without diatomaceous earth were evaluted.

On the basis of the results (Table 4), a 48 hour settling period produced the best results. Spot tests on this brine indicated carbohydrate present but

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Table 4. Turbidity and Settleable Solids of Raw and Treated Brines.

Treatment	Turbidity*	Settleable Solids ml
1. Raw Brine	820	200
2. Settled 24 hr.	180	0
3. Settled 24 hr. & Celite	120	0
4. Settled 48 hr.	85	0
5. Settled 48 hr. & Celite	75	0
6. #2 pH adjusted to 7.0	132	0
7. #3 pH adjusted to 7.0	90	0
8. #4 pH adjusted to 7.0	58	0
9. #5 pH adjusted to 7.0	50	0

*Turbidity is expressed in Jackson Turbidity Units.

no protein. Although it has not been definitely identified, the carbohydrate was possibly a pigmented artifact since pH adjustments changed the intensity of the color of the brine. It was not a fermentable sugar.

Cucumbers 3B in size were obtained and recycled brine was applied to these fruits. A control lot using new salt was made. Recycling was carried out over a six year period. There appeared to be no effect on quality of the finished product of the recylced brine. If anything, a quicker cure resulted using recycled brine. In point of fact, it appeared that fermentation appeared more rapidly and the cure obtained more quickly in direct relation to the number of recycles. In other words, the more frequently recycled the brine, the more rapid the cure obtained. It was also noted that the amount of bloating was significantly reduced using recycled brine.

Refinement Phase

Sand Filtration - Raw pickle brine was filtered through 18 inches of filter sand in an effort to remove the suspended solids. The speed of filtration was dependent upon gravity. This filter did not utilize a pump. The sand particle size ranged from 0.45-0.55 mm.

Sand filtration alone was not an adequate method for recycling spent brine. Filtration was slow without a pump. Less than 1 liter of filtrate was collected per minute. Prior chemical pretreatment was necessary in order to produce a reusable brine.

pH Adjustment followed by Polyelectrolyte Addition - The only polyelectrolyte capable of producing a large floc with the formation of a suspended sediment was

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Calgon WT 2900. The sequence of addition was extremely important. The pH had to be adjusted to 11 before WT 2900 was added. Any other sequence proved unsuccessful. A pH higher than 11 would inactivate the anionic polyelectrolyte. The polyelectrolyte was tested at different concentrations ranging from 2 to 40 ppm. Six ppm proved to be the ideal concentration. It produced a large floc which rose to the top of the container. Apparently during the mixing process, air bubbles were entrapped in the floc which caused it to rise instead of sink. With a four-hour delay between the addition of WT 2900 and pH adjustment, the ammonia generated as a result of protein degradation would have dissipated into the atmosphere. This would eliminate ammonia as a cause of the suspended sediment.

The annonic polyelectrolyte costs $2.50 per pound. The cost per 5,300 gallons of spent brine was less than 50 cents.

This procedure was tested at the J. M. Smucker Company in Medina, Ohio. Approximately 5,300 gallons of spent brine was adjusted to pH 11. Six ppm of WT 2900 was added and mixed. Within two hours, a layer of sediment less than 1 foot in depth had accumulated at the bottom of the vat. The decantable supernatent was clear without any suspended solids. This process was approximately 24 times faster than pH adjustment.

After pH adjustment and polyelectrolyte addition, the decantable liquid was treated for percent light transmittance at 587 nm using the Spectronic 20. In all cases the reconditioned brine transmitted 100% of the 587 nm light passed through the sample.

After reconditioning, the brine was adjusted back to pH 3.2 in order to remove the yellow color that was generated during pH adjustment. Adjustment back to pH 7 did not reduce the yellow color as much as did pH 3.2. This yellow color could be attributed to the carotenoid pigments that were once present within the cucumber.

SUMMARY AND CONCLUSIONS

Based on the data obtained it appears that salt brines can be recycled without deleterious effects on the salt stock pickles.

The recommended system for salt brine recycling includes:

1. Adjust pH to 11.0 with liquid sodium hydroxide
2. Add 6 ppm solution of anionic polyelectrolyte
3. Allow to settle (approximately 2 hours)
4. Decant clear brine
5. Adjust pH to 7.0 with acetic acid or vinegar

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6. Brine is ready for reuse
7. Precipitate could be incinerated or solar dried to recover any salt present and reduce disposal problems.

It has been shown that a quicker cure results from using recycled brine as well as a reduction in hollow pickle (bloater) formation. Recycling would save the pickle processor money in terms of surcharge and other disposal costs. In addition this system, if adopted, would eliminate potential saline pollution of our water supply.

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